Consultative Committee for Space Data Systems

DRAFT RECOMMENDATION FOR SPACE DATA SYSTEM STANDARDS

TELEMETRY

CHANNEL CODING

CCSDS 101.0-~~B~~P-5.1

~~BLUE BOOK~~PINK SHEETS

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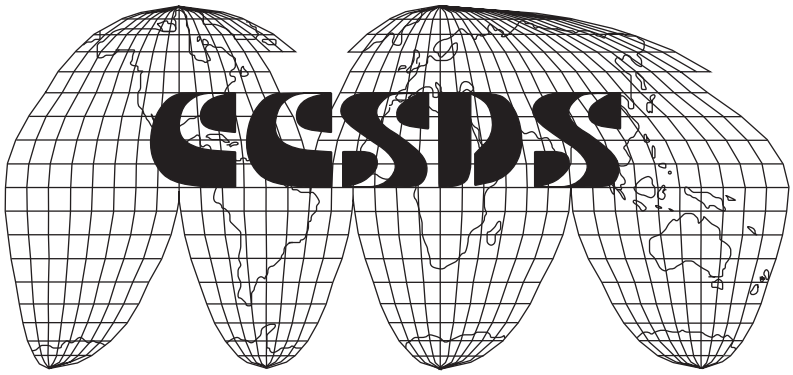

(a) J, E, and I (the depth of interleaving) are independent parameters.

(b) $n = 2^J - 1 = 255$ symbols per R-S codeword.

(c) $2E$ is the number of R-S symbols among n symbols of an R-S codeword representing parity checks.

(d) $k = n - 2E$ is the number of R-S symbols among n R-S symbols of an R-S codeword representing information.

(4) Field generator polynomial:

$$F(x) = x^8 + x^7 + x^2 + x + 1$$

over GF(2).

(5) Code generator polynomial:

$$g(x) = \prod_{j=128-E}^{127+E} (x - \alpha^{11j}) = \sum_{i=0}^{2E} G_i x^i$$

over GF(2^8), where F(α) = 0.

It should be recognized that α^{11} is a primitive element in GF(2^8) and that F(x) and g(x) characterize a (255,223) Reed-Solomon code when E = 16 and a (255,239) Reed-Solomon code when E = 8.

(6) The selected code is a systematic code. This results in a systematic codeblock.

(7) Symbol Interleaving:

The allowable values of interleaving depth are I=1, 2, 3, 4, ~~and~~ 5, and 8. I=1 is equivalent to the absence of interleaving. The interleaving depth shall normally be fixed on a physical channel for a mission. Symbol interleaving is accomplished in a manner functionally described with the aid of Figure 3-1. (It should be noted that this functional description does not necessarily correspond to the physical implementation of an encoder.)

6 PSEUDO-RANDOMIZER

6.1 INTRODUCTION

In order to maintain bit (or symbol) synchronization with the received telemetry signal, every ground data capture system requires that the incoming signal have a minimum bit transition density (see reference [3]).

~~If a sufficient bit transition density is not ensured for the channel by other methods (e.g., by use of certain modulation techniques or one of the recommended convolutional codes) then the Pseudo-Randomizer defined in this section is required. Its use is optional otherwise.~~
The Pseudo-Randomizer defined in this section is required unless a sufficient bit transition density is ensured for the channel by other methods.

The presence or absence of Pseudo-Randomization is fixed for a physical channel and is *managed* (i.e., its presence or absence is not signaled in the telemetry but must be known a priori) by the ground system.

6.2 PSEUDO-RANDOMIZER DESCRIPTION

The method for ensuring sufficient transitions is to exclusive-OR each bit of the Codeblock or Transfer Frame with a standard pseudo-random sequence.

If the Pseudo-Randomizer is used, on the sending end it is applied to the Codeblock or Transfer Frame after turbo encoding or RS encoding (if either is used), but before convolutional encoding (if used). On the receiving end, it is applied to derandomize the data after convolutional decoding (if used) and codeblock synchronization but before Reed-Solomon decoding or turbo decoding (if either is used).[1]

The configuration at the sending end is shown in Figure 6-1.

[1] "Derandomization" consists of either: a) exclusive OR-ing the pseudo-random sequence with the received bits of a transfer frame or a Reed-Solomon codeblock, *or* b) inverting (or not inverting), according to the pseudo-randomizer bit pattern, the demodulator output of a turbo codeblock.

E3 FRAME LENGTHS WITH REED-SOLOMON CODING

E3.1 GENERAL

With the Reed-Solomon Codes specified in Section 3, only certain specific lengths of transfer frames may be contained within the codeblock's data space. In some cases these lengths may be shortened in discrete steps by using virtual fill at a small sacrifice in coding gain. Since these R-S codes have a symbol length of 8 bits, the length of the codeblock must be a combined multiple of 8 bits and the interleaving depth. This will give "octet compatibility". If high-speed efficiency is needed for "32-bit compatibility" (with 32-bit processors, for example) then the length of the codeblock must be a combined multiple of 8 bits, the interleaving depth, and 32 bits.

NOTES

1 The Advanced Orbiting Systems Recommendation [2] specifies a limited set of codeblock lengths, and only the E=16 case for the channel code. It is undergoing revision by the CCSDS to include the E=8 option.

2 In each table below, lengths are given in bits with equivalent octets in (parentheses).

E3.2 TRANSFER FRAMES FOR OCTET COMPATIBILITY, E=16

The following are allowed lengths for Transfer Frames when octet compatibility is sufficient and the Reed-Solomon E=16 code is selected. Maximum lengths are shown; shorter lengths are permitted in discrete steps using the concept of "Virtual Fill" and shortening the transmitted codeblock length by the steps shown in the last column.

Reed-Solomon Interleave Depth (I)	Maximum Transfer Frame Length	Maximum Transmitted Codeblock Length, E=16	Transfer Frame (and transmitted codeblock) may be shortened in multiples of
1	1784 (223)	2040 (255)	8 (1)
2	3568 (446)	4080 (510)	16 (2)
3	5352 (669)	6120 (765)	24 (3)
4	7136 (892)	8160 (1020	32 (4)
5	8920 (1115)	10200 (1275)	40 (5)
8	14272 (1784)	16320 (2040)	64 (8)

E3.3 TRANSFER FRAMES FOR OCTET COMPATIBILITY, E=8

The following are allowed lengths for Transfer Frames when octet compatibility is sufficient and the Reed-Solomon E=8 code is selected. Maximum lengths are shown; shorter lengths are permitted in discrete steps using the concept of "Virtual Fill" and shortening the transmitted codeblock length by the steps shown in the last column.

R-S Inter-leave Depth (I)	Maximum Transfer Frame Length	Maximum Transmitted Codeblock Length, E=8	Transfer Frame (and transmitted codeblock) may be further shortened in multiples of
1	1912 (239)	2040 (255)	8 (1)
2	3824 (478)	4080 (510)	16 (2)
3	5736 (717)	6120 (765)	24 (3)
4	7648 (956)	8160 (1020)	32 (4)
5	9560 (1195)	10200 (1275)	40 (5)
8	15296 (1912)	16320 (2040)	64 (8)

E4 FRAME LENGTHS WITH TURBO CODING

The Turbo Codes specified in Section 4 of this Recommendation are block codes. Therefore, the frame length must match the information block lengths for the selected turbo code.

Performance for only the following information block lengths have been validated by CCSDS and approved for use. These lengths will accommodate both Version 1 Transfer Frames [1] and Version 2 VCDUs [2]. Values are in bits.

1784, 3568, 7136, 8920, 16384[1]

NOTES

1 Frame synchronizers should be set to account for the Attached Sync Marker, whose length must be added to the turbo codeblock length as specified in Table 4-2. The ASM pattern and length depend on the turbo code rate as shown in Figure 4-4.

2 Recommendations [1] and [2] require that if the Reed-Solomon Code is not used, a Cyclic Redundancy Check (CRC) is required as part of the Transfer Frame or VCDU for validation purposes.

[1] Interleaver parameters for the length 16384 bits are under study by the CCSDS. Until finalized, use of this option is not recommended.